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The Patent Office

Cardiff Road
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1. Your reference

R19210/MGO/JDB/GDM

2. Patent application number
(The Patent Office will fill in this part)

9701165.4

3. Full name, address and postcode of the or of each applicant *(underline all surnames)*

PUCHIANU, Silviu
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Patents ADP number *(if you know it)*

If the applicant is a corporate body, give the country/state of its incorporation

7139561001

4. Title of the invention

5. Name of your agent *(If you have one)*

Murgitroyd & Company

"Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*

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1198013 / 1826001

6. If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or of each of these earlier applications and *(If you know it)* the or each application number

Country	Priority application number *(if you know it)*	Date of filing *(day / month / year)*

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Number of earlier application	Date of filing *(day / month / year)*

8. Is a statement of inventorship and of right to grant of a patent required in support of this request? *(Answer 'Yes' if:*

a) any applicant named in part 3 is not an inventor, or
b) there is an inventor who is not named as an applicant, or
c) any named applicant is a corporate body.
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Continuation sheets of this form	–
Description	25
Claim(s)	–
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Priority documents	–
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Statement of inventorship and right to grant of a patent *(Patents Form 7/77)*	–
Request for preliminary examination and search *(Patents Form 9/77)*	–
Request for substantive examination *(Patents Form 10/77)*	–
Any other documents *(please specify)*	–

11. I/We request the grant of a patent on the basis of this application.

Signature Murgitroyd & Company Date 21/1/97

12. Name and daytime telephone number of person to contact in the United Kingdom

Graeme D McCallum 01224 706616

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Notes

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Battery Life Determination Using An Intelligent Battery-Life Monitor Circuit

1) *The Principle*

One of the most important requirements in battery based systems is to determine when the battery(ies) is/are to be replaced (their 'end-of-life'). An indication about the battery life is the calendar life specified by the manufacturer but the actual life of a specific battery is heavily dependent on factors such as the charge algorithm, charge parameters (current/voltage regime in time), temperature, mechanical shocks or vibration regime, type of usage (cyclic or floating), etc..

For Lead batteries, at the time the cells or batteries are shipped, they are at 80 per cent state of charge or better. In use, either cycling or float-charge, they improve in capacity and after a few cycles they reach their rated capacity and they stabilise at or somewhat above 100 per cent of their rated capacity . With continued use then a very gradual decline in capacity begins, their end-of-life point being usually defined as 80 per cent of the rated capacity.

For Nickel-Cadmium batteries a capacity of less than 50 per cent of the new capacity at operating conditions is often used as an indication of the end-of-life.

In conclusion, for a specific battery, to determine the actual battery capacity (measured in Ampere-hour) versus time characteristic is the best way in predicting their end-of-life and replaces it before the actual battery failure.

2) *The Method*

In determining battery life, the method envisaged is to discharge battery at reasonable intervals (months), measure the actual battery capacity, compare it with the previous measurements and decide, based on a the battery-life characteristic, when the battery is toward it's end-of-life (see Fig. 1).

For a specific battery, periodic discharge cycles are to be performed in order to determine the battery-life characteristic and predict it's end-of-life.

3 A

STATEMENT OF INVENTION

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According to a first aspect, the present invention provides a method of monitoring the charge held within a battery comprising the steps of:-

(a) systematically measuring preselected parameters of the battery;
(b) discharging the battery through a load from a first level of charge to a second level of charge over a time period;
(c) calculating the usable charge held within the battery from the measured preselected parameters by using a microcontroller; and
(d) outputting the value of usable charge.

Preferably, the preselected parameters are battery voltage, current and battery temperature.

Typically, the first level of charge is where the battery is fully charged. Preferably, the second level of charge is where the battery is devoid of usable charge.

Typically, the usable charge is calculated by integrating the current discharged in time.

Preferably, the load is a working load, such that the charge held within the battery is discharged on a changing load.

This provides the advantage that the battery charge can be monitored whilst the battery is discharged through a working load, and therefore does not require the battery to be disconnected from the working load, and connected to a constant dummy load.

According to a second aspect of the present invention there is provided a method of monitoring the impedance of a battery comprising the steps of:-

(a) systematically measuring preselected parameters of the battery on load;
(b) calculating the difference in two or more of the measured preselected parameters as they change;
(c) calculating the internal impedance of the battery from the calculated difference of the measured preselected parameters by using a microcontroller; and
(d) outputting the value of internal impedance.

Preferably, the preselected parameters measured for which the differences are calculated are battery voltage and current supplied to the load.

3B

Typically, the impedance of the battery is calculated by dividing the calculated difference in voltage by the calculated difference in current.

This has the advantage that two dummy loads are not required to measure the impedance of the battery, as the change in voltage and the change in current is measured systematically whilst the battery is supplying a load.

Typically, the preselected parameters are systematically measured in real time.

/u/mur/recordals/r19210-

3) *The Intelligent Battery-Life Monitor*

In Fig.2 the block-schematic for the Intelligent Battery-Life Monitor, an electronic circuit which implements the above mentioned method, is given.

The circuit is used to:

a) select the discharge parameters for a specific battery type,

b) manually or automatically record the specific battery identity code,

c) discharge the battery in order to measure it's capacity by integrating the discharge current in time,

d) compare the actual capacity value with the previous capacity measurements,

e) using the battery type-specific life characteristic, automatically determine when the battery is close to it's end-of-life and/or what is the life expectancy for the specific battery,

f) graphically display the battery-life characteristic for the battery under investigation (optional).

g) download the information to a host-computer for further processing and statistical analysis (optional).

3.1. System Description

The Intelligent Battery Monitoring System SP003 is designed to monitor all the battery parameters for 400 Volts industrial batteries of any capacity.

The system is completely independent of external power supplies, being powered from the monitored battery and is capable of:

- accurate measurement of :
  - *Total Battery Capacity (in Amps.Hour),*
  - *Actual Battery Capacity (in % of total capacity),*
  - *Battery Impedance.*
- real-time monitoring and local displaying of the:

  *1) **Battery Data Pack** (voltage, charge/discharge current, temperature actual and total battery capacity),*

  *2) **Battery Status** (charging/ , discharging mode, over current, over/under voltage and over temperature).*
- remote alarms for critical events (over current, over/under voltage and over temperature).
- storing of all the battery parameters for up to 8 weeks, a full Battery Data Pack being stored in the 8 Mbytes internal memory at 10.5 seconds intervals together with the date/time stamp.
- direct interfacing to PC for:
  - *system control, initialisation and operating mode selection,*
  - ***Data File** retrieval (the Battery Bata Packs for the monitoring or logging period),*
  - ***Events File** retrieval (only the significant events for the monitoring or logging period).*
- charger control for efficient and correct battery charging.

The system comprises of a hardware unit continuously monitoring the battery and two PC-resident softwares, ***SP003 Monitor*** and ***SP003 Retrieve***.

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The front panel displays are:

- the CAPACITY (%) display, for the actual battery capacity value as percentage of the total battery capacity.
- the STATUS display, for battery status information; the monitored conditions are:

  1) "dc", to indicate that the battery is in discharge mode (backup mode),

  2) "Oc", to indicate an over-current condition in discharge mode (Ibatt > 170 Amps),

  3) "Ou", to indicate an over-voltage condition (Vbatt > 425 Volts),

  4) "Uu", to indicate an under-voltage condition (Vbatt < 400 Volts),

  5) "Ot", to indicate an over-temperature condition (T > 24 Deg.C).
- the Voltage/Current/Temperature display, for the actual values of these parameters.
- the operating mode display, indicating one of the following operating modes:

  1) **LOGGING** (every 10.5 seconds the Battery Data Pack is logged to the internal memory),

  2) **MONITOR** (the battery may be monitored in real time using an external PC and the RS232 serial interface),

  3) **MEMORY** (the operator has access to the internal memory in order to retrieve data and set the system ready for the next monitoring/logging period),

  4) IDLE (data is displayed but not logged or available for real-time monitoring and the access to the internal memory is disabled).

The unit is monitoring voltage, current and temperature using the following connectors:

1) the voltage sense pair of connectors, connected to the two battery terminals; this connector pair is also used to supply the unit with power.

2) the current sense connector (Hall effect current sense device).

3) temperature connector, for the current sense device.

When used in conjunction with an external PC, the RS232 serial interface connector is used. The Alarms connector is a volt-free link to the control room allowing the user to have remote information, with the following functions:

1) Over-current alarm, for Ibatt > 170 Amps in discharge mode,

2) Over-voltage alarm, for Vbatt > 425 Volts, in charge and discharge mode,

3) Under-voltage alarm, for Vbatt < 400 Volts, in charge and discharge mode,

4) Over-temperature alarm, fir T > 24 Deg.C, in charge and discharge mode.

The said alarms are updated every 10.5 seconds.

3.1.2 System Software Description

There are two softwares available with SP003.

- **SP003 MONITOR** for real-time battery monitoring (to be used in MONITOR mode), and
- **SP003 RETRIEVE** for retrieving data for the internal memory (in LOGGING mode) and for initialising the system prior to a new logging session (in MEMORY mode).

Before proceeding with the software description, a summary of the available modes of operation is necessary.

3.1.2.1 Modes Of Operation

There are 4 modes of operation:

1) **IDLE**

The system monitors the full battery data pack and displays it on the front panel. Data is not logged to the internal memory and RS232 communication with the system is disabled. All alarms are enabled.

2) **MONITOR**

The system monitors the full battery data pack and displays it on the front panel. Data is not logged to the internal memory and RS232 communication with the system is enabled. The real-time battery data pack is available on the RS232 interface using the SP003 MONITOR software.

This mode of operation is suitable for:

a) real-time monitoring,

b) total battery capacity measurement.

c) battery impedance measurement.

3) MEMORY

The system monitors the full battery data pack and displays it on the front panel. Data is not logged to the internal memory and RS232 communication with the system is enabled. Access to the internal memory is allowed using SP003 RETRIEVE software.

This mode of operation is suitable for:

a) retrieving logged data and software filtered events from the internal memory to PC's hard disk, and

b) initialising the system prior to a new logging session.

4) LOGGING

The system monitors the full Battery Data Pack and displays it on the front panel. Data is logged to the internal memory and RS232 communication with the system is disabled. The battery data packs are logged to the internal memory every 10.5 seconds.

This mode of operation is suitable for long time unattended monitoring.

3.1.2.2 The SP003 MONITOR Software

The SP003 MONITOR software allows for:

1) establishing communication between the SP003 unit and PC,

2) real-time battery monitoring,

3) displaying of battery parameters/events in graphical and text form,

4) Battery Data Pack (all battery parameters date/time stamped) logging to hard disk,

5) Events monitoring (only significant events are logged to hard disk),

6) battery total capacity measurement,

7) battery impedance measurement,

8) setting of initial battery capacity to 100% for a fully charged battery,

9) operating mode selection.

The SP003 MONITOR window is partitioned as follows:

1) the BATTERY PARAMETERS window, used for displaying the Battery Data Pack (sample time, total capacity, actual capacity, charging/discharging current, battery voltage, temperature and last measured impedance),

2) the BATTERY STATUS window,

3) the SYSTEM OPERATION (Mode) window, displaying system status and mode of operation,

4) the graph window for historical parameter trend or individual graphs, covering the battery behaviour for the last 20 minutes; the same window is used to display in text form a list of the significant events,

5) a symbolical representation of battery, charger and load showing the actual charge level.

A description of the menu items follows.

The ***Communication*** section allows for selection of the RS232 serial port to be used. After selecting it, the port should be open.

The ***Mode*** section allows for:

- selecting the IDLE or MONITOR mode,

- checking of system configuration (actual status and system identity)

- setting of initial battery capacity. Only after the system lock in checked the operator may modify the initial battery capacity. Some erroneous data might be displayed for one or two consecutive readings.

The ***Display*** section allows for selecting the trend graph, single graphs or the event list.

The ***Event File*** section allows for storing to the hard disk of events, in the C:\tq1\event_rt.out file. If the Regular Checks/Log Regular Checks and the interval for regular checks is selected, periodically full Battery Data Packs are stored in the event file and displayed in the event list. The file should be cleared before starting it, otherwise data will be appended to old data.

The ***Data File*** section allows for storing to the hard disk of all the battery data packs in the C:\tq1\data_rt.out file. The file should be cleared before starting it, otherwise data will be appended to old data.

The ***New Capacity*** section allows for informing the system that a total capacity measurement will be initiated. Before activating it, the user must make sure that the battery is fully charged, Vbatt > 410 Volts and actual battery capacity is 100%. After activating the said menu, the battery must be set in discharge mode until the battery voltage reaches less than 364 Volts (**EODV** or End Of Discharge Voltage limit) and the indication for total capacity in the BATTERY PARAMETERS window changes to the new value. Then the battery must be set in charging mode

3. *1.2.3 The SP003 RETRIEVE Software*

The SP003 RETRIEVE software allows for:

1) establishing communication between the SP003 unit and PC,

2) selecting one of MEMORY, LOGGING, IDLE modes of communication,

3) checking the system configuration (status or system identity),

4) initialising the SP003 unit prior to a new logging session,

5) retrieving all the Battery Data Packs from SP003's internal memory and saving the information to the hard-disk,

6) filtering the information from the last logging session and constructing an event file containing only the significant information (called here events).

The SP003 RETRIEVE window is partitioned as follows:

1) the ***System Operation Mode*** window,

2) the ***System Status*** window,

3) the ***Battery Data Set*** window,

4) The ***Battery Status Information*** window (for manufacturer test only).

A description of the menu items follows.

The ***Communication*** section allows for selection of the RS232 serial port to be used. After selecting it, the port should be open.

The ***Mode*** section allows f or:

- selecting of MEMORY, IDLE or LOGGING mode. Selecting the LOGGING mode will be allowed only if the system was correctly initialised (system clock was set to the actual data and time, the memory was set at the beginning and checked and the No. of records was reset to zero and checked).

- checking of system configuration (actual status and system identity)

The ***System Memory*** section allows for setting and checking of parameters for the internal memory, like:

- ***Internal Clock***, setting to the actual time/date and checking it.

- ***Memory Size***, in steps of 1 Mbytes. The memory size should reflect the actual no. of memory chips installed on the memory board (typically 8 Mbytes, allowing for 8 weeks of continuous battery data packs logging)

- ***Memory Address***, checking the actual value and setting memory to beginning.

- ***Number Of Records***, for checking how many are in the internal memory and resetting; a "Record" is a complete Battery Data Pack date/time stamped.

- ***Upload Records (F1)*** will retrieve one Record (Battery Data Pack) from the next memory location and display it in the Battery Data Set window.

The ***Event File*** section allows for retrieving of events from the internal memory. The file C:\tq1\event_lg.out will be retrieved to the hard disk only if the address was set at the beginning of the internal memory and checked and the no. of records checked. It is also recommended to check system identity before retrieving the event file, so that it is recorded. Regular checks may be inserted. The file should be cleared before starting it, otherwise data will be appended to old data.

The ***Data File*** section allows for retrieving of all data packs from the internal memory. The file C:\tq1\data_lg.out will be retrieved to the hard disk only if the address was set at the beginning and checked and the no. of records checked. It is also recommended to check system identity before retrieving the event file, so that it is recorded. The file should be cleared before starting it, otherwise new data will be appended to old data.

3.2. System Installation

The Intelligent Battery Monitoring System SP003 installation procedure is described here.

3.2.1 Hardware Installation

1) Connect the Voltage Sense/Power cable at the "BATTERY" connector on the SP003 unit (red for "+", black for "-"). Do not connect to battery terminals yet.
2) Connect the Current Sense cable to the "I SENSE" connector (4 pins) on the SP003 unit. Do not attach to the battery terminal yet. Each SP003 unit is calibrated to use it's own dedicated Current Transducer and only the respective Current Transducer (see the cable label) should be used.
3) Connect the Temperature Sense cable to the "T.SENSE" connector (2 pins) on the SP003 unit. Do not attach to the battery yet. Each SP003 unit should is calibrated to use it's own dedicated transducer and only the respective Temperature Transducer (see the cable label) should be used.
4) Make sure the battery is being charged and the battery voltage is within charger's manufacturer recommended limits (400 < Vbatt< 425 Volts).
5) Connect the "-" (black) terminal of the Voltage Sense/Power cable to the "-" (negative) battery terminal. Connect the "+" (red) terminal of the Voltage Sense/Power cable to the "+" (positive) battery terminal. The IDLE LED is ON and after few seconds the unit is operational and the front panel displays are active.
6) Make sure the battery is being charged and the battery current is within the recommended limits for the Current Transducer (less than 200 Amps in absolute value).
7) Attach the clamp Current Transducer to battery's positive terminal, with the arrow facing away form the terminal and as close to the terminal as possible.
8) Install the Temperature Sensor on the battery pack.
9) Check that the indications on SP003's front panel are consistent with charger's characteristics. The actual battery capacity indication should be ignored at this stage and will be software set later.

10) Connect the Alarm Cable to SP003's AL1 connector. This is a volt free contact and it's maximum ratings (max.0.4 Amps, max.50 Volts) should not be exceed under any circumstances. This cable is to be routed to user's control room.

3.2.2 Software Installation

To install SP003 MONITOR:

1) Insert Disk 1 (of 4) for SP003 MONITOR software in the floppy-disk drive and use Windows Explorer to access Disk 1.
2) Double click in the SETUP application. The installation procedure will start.
3) Follow the instructions on the screen to complete the installation procedure.
4) Check that the SP003 MONITOR folder was added to your start-up window.

To install SP003 RETRIEVE:

1) Insert Disk 1 (of 4) for SP003 RETRIEVE software in the floppy-disk drive and use Windows Explorer to access Disk 1.
2) Double click in the SETUP application. The installation procedure will start.
3) Follow the instructions on the screen to complete the installation procedure.
4) Check that the SP003 RETRIEVE folder was added to your start-up window.

Make a new directory C:\TG1. This will be used by SP003 MONITOR and SP003 RETRIEVE for the files containing the battery data and events information.

Note: The minimum configuration for the laptop PC used is:

- Windows 95 operating system.
- min. 120 Mbytes of hard-disk available,
- min.16 Mbytes of RAM,
- min. 120 MHz processor.
- RS232 serial port available for link with the SP003 unit.
- Microsoft Word for Windows 95 (at least version 7.0).

3. Using The Battery Monitoring System

The SP003 Battery Monitoring System may be used to:

1) monitor battery parameters and charger functionality in real-time using the front panel displays.

2) monitor battery parameters and charger functionality in real-time and log data to hard-disk using a laptop PC.

3) log battery/charger data to the 8 Mbytes internal memory every 10.5 seconds for long periods of time (up to 8 weeks for an uninterrupted logging period).

4) retrieve and filter the data stored in the internal memory, in order check the battery and charger functionality and take corrective action, if necessary,.

5) measure the real total battery capacity (in Amps.Hour) for the specific battery pack and use it as the realistic reference for the actual instantaneous battery capacity (as percentage of the total battery capacity). If this measurement is performed at regular intervals of time, the battery life characteristic may be build and battery's end of life predicted with high accuracy.

6) measure battery's impedance; the impedance is automatically calculated by system software whenever a significant variation of the load is detected, when in discharge mode. This allows to estimate the usability of the specific battery and to detect an eventual significant increase in the impedance; thus corrective action may be taken by the user (battery or cell replacement, etc).

3.1 Using SP003 For Real-Time Monitoring

SP003 may be used to monitor battery's status and parameters in IDLE mode (using the front panel displays and the Alarm Cable only) and in MONITOR mode (using the above and a Laptop PC equipped with the SP003 MONITOR software).

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3. 3.1.1 Real-Time Monitoring In IDLE Mode

The real-time monitoring in the IDLE mode is based only on the front panel indications using the local displays. It also encompasses the alarms being send through the Alarms Cable to the control room.

3. 3.1.2 Real-Time Monitoring In MONITOR Mode

With the SP003 hardware unit installed and the PC equipped with the SP003 MONITOR software, real-time battery/charger monitoring is possible. To start the real-time monitoring session, the procedure is as follows (it is assumed that the hardware and software installation were already performed):

1) Link the SP003 unit and the PC using the RS232 link.
2) Start the SP003 MONITOR software (in full-screen Windows mode).
3) Select (click) ***Communication/Select communication port/Comm. Port 1,2,3 or 4*** (depending which port is used by the system).
4) Select ***Communication/Open communication port.*** The SYSTEM OPERATION (Mode) window should inform about the actual mode of operation, which should be the same with the one indicated by the front pane LEDs.
5) Select ***Mode/Set System In MONITOR Mode.*** Check that the front panel MONITOR LED is ON and the SYSTEM OPERATION window indicates the MONITOR mode. After few seconds the BATTERY PARAMETERS window will start displaying the full Battery Data Pack and the graphical window will show the trend graph for all battery parameters. The BATTERY STATUS window will indicate the current battery operation (charging, discharging etc.)

3. 3.1.2.1 Real-Time On-Screen Information

To visualise individual historical graphs, select ***Display/Single Plots/Charge (%)vs. Time*** , ***Voltage (V) vs. Time***, ***Current (A) vs. Time***, ***Temperature (Deg. C) vs. Time*** or ***Impedance (Ohm) vs. Time.***

To visualise only the significant events, select ***Display/Display Events***. A list of significant events is displayed instead of graphs.

Regular checks (full Battery Data Packs) may be displayed, if necessary, by selecting ***Event File/Regular Checks/Log Regular Checks/Every 1,2,5,10,30 Min.*** This feature is desirable for long periods of real-time monitoring lacking in significant events.

3.1.2.2 Real Time Data File Logging To Hard Disk

To save all the Battery Data Packs, select ***Data File/Start Logging Data To Hard Disk***. From now on, all the Battery Data Packs (every 10.5 seconds) will be logged to the hard disk in the file C:\TG1\data_rt.out. To stop the process, select ***Data File/Stop Logging Data To Hard Disk.***

To initialise the data file, select ***Data File/Clear/Stop Data File (data_rt.out)***. The old data file will be erased. Since all previously recorded data will be lost, it is good practice to save (if desirable) the previous file under a separate name, for further reference.

3.1.2.3 Real Time Event File Logging To Hard Disk

To filter data from the Battery Data Packs and log to hard disk only the significant events, select ***Event File/Start Logging Events To Hard Disk***. From now on, only significant events will be logged to the hard disk in the file C:\TG1\event_rt.out. To stop the process, select ***Event File/Stop Logging Events To Hard Disk.***

To initialise the data file, select ***Event File/Clear/Stop Events File (event_rt.out)***. The old data file will be erased. Since all previously recorded data will be lost, it is good practice to save (if desirable) the previous file under a separate name, for further reference.

Regular checks (full Battery Data Packs) may be recorded in the event_rt.out file, if necessary, by selecting ***Event File/Regular Checks/Log Regular Checks/Every 1,2,5,10,30 Min***. This feature is desirable for long periods of real-time monitoring lacking in significant events.

3.2 Using SP003 For Setting The Initial Capacity To 100% For A Fully Charged Battery

When installing the SP003 hardware unit for the first time on a specific battery, there is no way for the system to detect how "full" the battery is and the system will usually indicate 0% actual charge.

When a 100% charge is assumed by the user, the SP003 system must be set for 100% charge display, as follows:

1) Perform all steps described in par.3.3.1.2, in order to start the SP003 MONITOR software.
2) Select (click) ***Mode/Set/Reset Initial Capacity/Toggle And Check System Lock.*** The SYSTEM OPERATION window will inform of the actual status of the system lock.

3) If the system is unlocked, select ***Mode/Set/Reset Initial Capacity/Set Capacity To 100%***. The next one to two Battery Data Packs readings may be erroneous and should be ignored. If after that the displayed capacity is not 100% repeat step 3.

4) If the system is locked, click again ***Mode/Set/Reset Initial Capacity/Toggle And Check System Lock*** until the system unlocks, then perform step 3.

5) After the displayed charge is set to 100%, reselect ***Mode/Set/Reset Initial Capacity/Toggle And Check System Lock*** until the system is locked. Check system lock status using the SYSTEM OPERATION window.

3.3.3 Using SP003 For Measuring The Total Battery Capacity

When installing the SP003 hardware unit for the first time on a specific battery, there is no way for the system to detect the battery total capacity and the system will start with an initial assumed total capacity, which is the nominal and not the real battery capacity for the specific battery.

SP003 is designed to accurately determine the actual battery capacity. For this to happen it is necessary to perform a battery discharge from "full" to the EODV (End Of Discharge Voltage limit = 364 Volts). The system will monitor the discharge current and take into consideration battery-specific charge/discharge .vs. temperature and charging/discharging current characteristics in order to accurately determine the real total capacity. From then on, the actual battery capacity (percentage of the total charge) will accurately reflect the real available charge. The procedure is as follows:

1) Perform all steps described in par.3.3.1.2, in order to start the SP003 MONITOR software.

2) Check that the battery is fully charged, (the battery was charged for a long period of time, the charger is in "trickle" charge mode and the battery voltage is greater than 410 Volts).

3) Check that the displayed charge is 100%. If necessary, set the actual charge to 100% (see par. 3.2).

4) Select (Click few times!) ***New Capacity/Start Capacity Measurement Cycle***. The next one to two Battery Data Packs readings may be erroneous and should be ignored.

5) Set the battery in discharge mode.

6) Monitor the battery voltage until it reaches aprox. 364 Volts. In the same time read the CAPACITY indication in the BATTERY PARAMETERS window changes to the new value. *When **both** conditions (Vbatt < 364*

*Volts **and** the CAPACITY indication on the screen changes), set the battery in charging mode.*

The new battery capacity will from now on be used by SP003 as reference for calculating the actual battery capacity as percentage of the total battery capacity.

3.3.4 Using SP003 For Measuring Battery Impedance

The procedure is as follows:

1) Perform all steps described in par.3.3.1.2, in order to start the SP003 MONITOR software.
2) Set the battery in discharge mode and simulate a load variation (e.g. from a discharge current of 40 Amps to a discharge current of 80 Amps)
3) The IMPEDANCE indication on the BATTERY PARAMETERS window will show the last measured battery impedance. The same value will be recorded in the events list and the events file (if enabled)

3.3.5 Using SP003 For Long Time Battery Data Logging

SP003 is capable of unattended battery monitoring and data logging for very long periods of time. The system may be used to monitor and log the Battery Data Packs to the internal system memory every 10.5 seconds for up to 8 weeks

3.3.5.1 Initialising SP003 For Long Time Monitoring

SP003's internal memory and internal date/time must be set to an initial status prior to setting the system in LOGGING mode. The procedure is as follows:

1) Link the SP003 unit and the PC using the RS232 link.
2) Start the SP003 RETRIEVE software.
3) Select (click) ***Communication/Select communication port/Comm. Port 1,2,3 or 4*** (depending which port is used by the system).
4) Select ***Communication/Open communication port.*** The SYSTEM OPERATION (Mode) window should inform about the actual mode of operation, which should be the same with the one indicated by the front pane LEDs.

5) Select ***Mode/Set System In MEMORY Mode***. Check that the front panel MEMORY LED is ON and the SYSTEM OPERATION MODE window indicates the MEMORY mode.

6) Check that PC's calendar/clock is set for the correct date and time.

7) Select ***System Memory/Internal Clock/Set To Actual Time*** and check system response in the SYSTEM STATUS window. To check, select ***System Memory/Internal Clock/Check*** and verify in the SYSTEM STATUS window.

8) Select ***System Memory/Memory Address/Set Memory At The Beginning*** and check system response in the SYSTEM STATUS window. To check, select ***System Memory/Memory Address/Read And Display Current Address*** and verify in the SYSTEM STATUS window.

9) Select ***System Memory/ Number Of Records/ Reset No. Of Records And Memory Address*** and check system response in the SYSTEM STATUS window. To check, select ***System Memory/ Number Of Records/Check No. Of Records*** and verify in the SYSTEM STATUS window that the no. of records was reset to zero. This operation will erase the no. of records for the previous logging session; that is why the system will once more time interrogate the user about the operation before performing it. The previous logging session data will be lost after this operation and the user must make sure that the data from the previous logging session was correctly retrieved and saved before performing it.

10) Select ***Mode/Set System In Logging Mode***. If the previous steps were correctly performed, the front panel LOGGING LED is ON and the SYSTEM OPERATION MODE window will show the LOGGING mode being selected. If not an error message will appear in the SYSTEM STATUS window and the procedure must be repeated.

11) Disconnect the RS232 cable. It is imperative that during the LOGGING mode, and for that matter for any selected mode, the SP003 hardware unit should under any circumstances be disconnected from the battery. If this happens the system will automatically go in IDLE mode and the logging session is aborted. However data is not lost and is still available in the internal memory, which will be backed by it's own internal battery for at least 2 weeks.

3.3.5.2 Retrieving The Logged Data After Long Time Monitoring

The procedure is as follows:

1) Link the SP003 unit and the PC using the RS232 link.

2) Start the SP003 RETRIEVE software.

3) Select (click) ***Communication/Select communication port/Comm. Port 1,2,3 or 4*** (depending which port is used by the system).

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4) Select ***Communication/Open communication port***. The SYSTEM OPERATION (Mode) window should inform about the actual mode of operation, which should be the same with the one indicated by the front pane LEDs.

5) Select ***Mode/Set System In MEMORY Mode***. Check that the front panel MEMORY LED is ON and the SYSTEM OPERATION MODE window indicates the MEMORY mode.

6) Select ***Mode/Check System Configuration/System Identity*** and check system's answer in the SYSTEM OPERATION MODE window.

7) Check that PC's calendar/clock is set for the correct date and time.

8) Select ***System Memory/Internal Clock/Check*** and check system response in the SYSTEM STATUS window.

9) Select ***System Memory/Memory Address/Set Memory At The Beginning*** and check system response in the SYSTEM STATUS window. To check, select ***System Memory/Memory Address/Read And Display Current Address*** and verify in the SYSTEM STATUS window.

10) Select ***System Memory/ Number Of Records/Check No. Of Records*** and verify in the SYSTEM STATUS that there are records in the internal memory. Do not reset the no. of records since this will prohibit the retrieval of data from the internal memory!

One of two operations are available to the user and it should be remembered that any time one of these operations are selected, steps 9 and 10 must be repeated in order for the internal system memory to be set in the pre-uploading initial state.

3. *3.5.2.1 Data File Logging To Hard Disk*

To initialise the data file, select ***Data File/Clear The Data File (data_lg.out)***. The old data file will be erased. Since all previously recorded data will be lost, it is good practice to save (if desirable) the previous file under a separate name, for further reference.

To save all the Battery Data Packs logged to the hard disk, first select ***Data File/Start Retrieving Data From The System Memory***. All the Battery Data Packs will be saved to the hard disk in the file C:\TG1\data_lg.out. To stop the process, select ***Data File/Stop Retrieving Data From The System Memory.***

If the process is not stopped by the user, the data retrieval procedure will proceed until all the logged Battery Data Packs are saved to the hard disk. The SYSTEM STATUS window will indicate at all times the operation being performed.

3. *3.5.2.2 Event File Logging To Hard Disk*

To initialise the event file, select ***Event File/Clear Events File (event_lg.out)***. The old event file will be erased. Since all previously recorded data will be lost, it is good practice to save (if desirable) the previous file under a separate name, for further reference.

To filter and save the events to the hard disk, first select ***Event File/Start Retrieving Events From The System Memory***. All the events will be filtered and saved to the hard disk in the file C:\TG1\event_lg.out. To stop the process, select ***Event File/Stop Retrieving Events From The System Memory.***

If the process is not stopped by the user, the data retrieval procedure will proceed until all the logged Battery Data Packs are saved to the hard disk. The SYSTEM STATUS window will indicate at all times the operation being performed.

Regular checks (full Battery Data Packs) may be recorded in the event_lg.out file, if necessary, by selecting ***Event File/Regular Checks/Upload Regular Checks/Every 10,100,200,500,1000 Records***. This feature is desirable for long periods of data logging lacking in significant events.

3. 4. Data And Event Files

3.4.1 Data And Event Files From SP003 MONITOR

The SP003 MONITOR software will output the following files:

1) C:\TG1\data_rt.out, containing the Battery Data Packs acquired and saved during the real-time monitoring procedure.

2) C:\TG1\event_rt.out, containing the information filtered and statistically analysed and compiled by the said software.

3.4.2 Data And Event Files From SP003 RETRIEVE

The SP003 RETRIEVE software will output the following files:

1) C:\TG1\data_lg.out, containing the Battery Data Packs acquired and saved during the last logging procedure,

2) C:\TG1\event_lg.out, containing the information filtered and statistically analysed and compiled by the said software.

4.3 The Event File Configuration

The event files contain information like:

- **CHARGER REGIME CHANGE**, for variations in voltage and/or current when the battery is in charge mode.

- **LOAD REGIME CHANGE**, for variations in voltage and/or current when the battery is in discharge mode.

- **TEMPERATURE CHANGE**, for variations of temperature.

- **IMPEDANCE MEASUREMENT**, for battery in discharge mode and conditions for impedance measurement met.

- **CAPACITY CHANGE**, for variations in capacity.

The rate of change is automatically detected by the software and sudden changes are sensed and indicated by attaching a **HIGH GRADIENT** warning to the above indications, with the exception of the capacity indication.

REGULAR CHECKS (at selected periods of time or after a certain number of consecutive records) may be optionally attached to the event file.

3. 4.4 Accessing The Data And Event Files

To access the data and event files saved to the hard disk It is recommended that a text editor software capable of accessing very large files is used, like Microsoft Word for Windows 95 (at least version 7.0).

Do not attempt to access the files while the SP003 MONITOR or SP003 RETRIEVE are writing to the said files and after using Word to access them, make sure the files are saved under a different name and closed before attempting another retrieval to the hard disk.

Make sure at least 40 Mbytes of hard disk are available at all times for new retrievals of data and/or event files.

4) *Applications*

4.1 Service Tool for Battery-Based Systems

In environments where multiple battery-based systems are used, as computer systems/networks equipped with Uninteruptable Power Supplies, to know in advance when a specific battery is to be replaced is very important.

In these environments a single service tool based on the Intelligent Battery-Life Monitor circuit may be used to periodically service all the batteries in the system in turn and at the most appropriate time, and avoid work interruptions due to unexpected battery failures.

4.2 Individual Battery-Failure Signal Generation

More expensive individual battery packs may be equiped with the Intelligent Battery-Life Monitor device emulating the features c, d, e, f and g described in par. 3, the said circuit being used to flag the eventual battery failure by determining the closeness to the battery end-of-life.

The battery discharge procedure can be automatically or manually initiated. In the automatic mode, at preset time intervals (months usually) charge-recharge cycles are initiated in order to determine the specific battery life characteristic.

5) *Technology*

The basic functions performed by the Intelligent Battery-Life Monitor are implemented using off-the-shelf components such as memories, microcontrollers, graphical-displays, computer interfacing IC's, etc.

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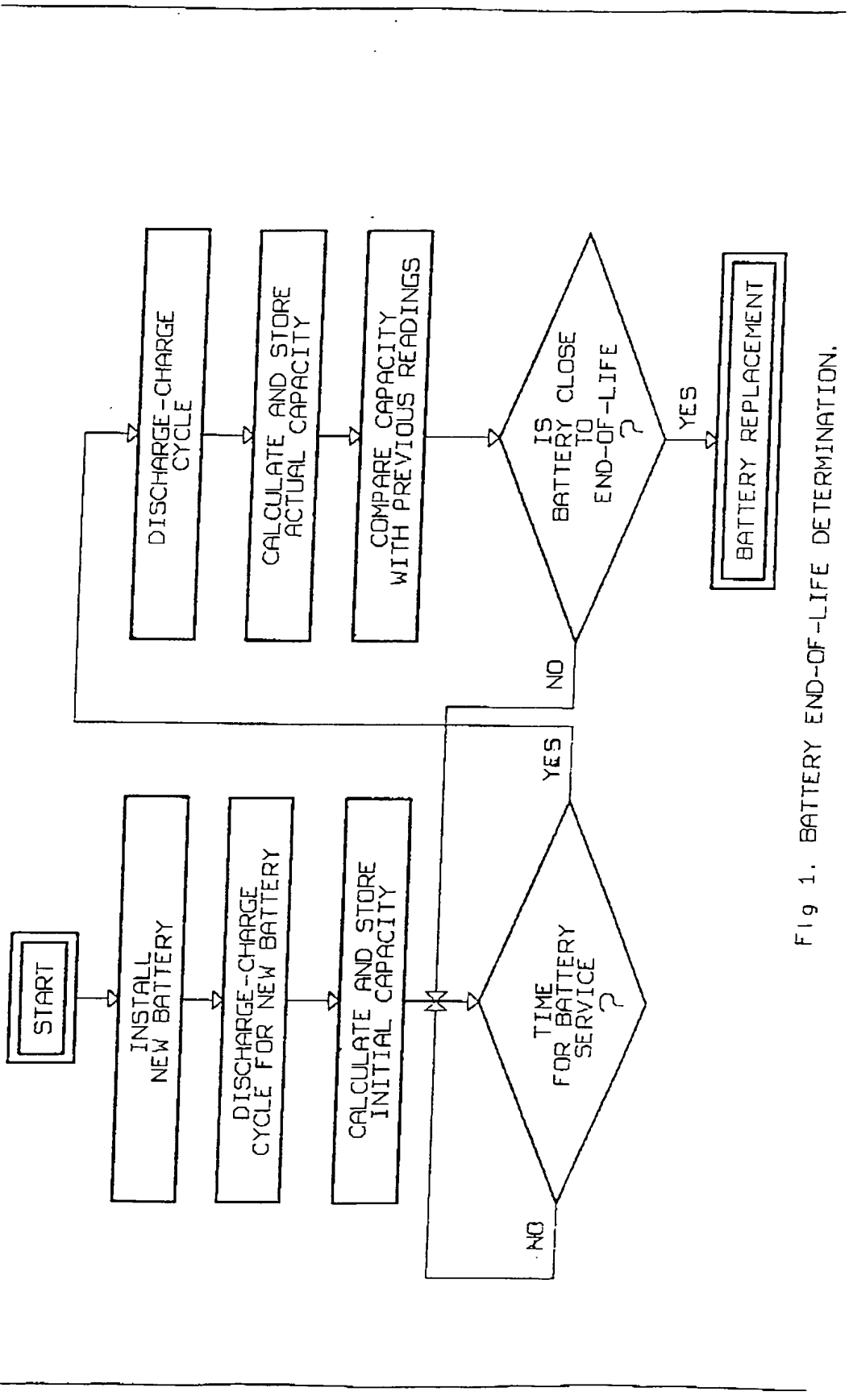

Fig 1. BATTERY END-OF-LIFE DETERMINATION.

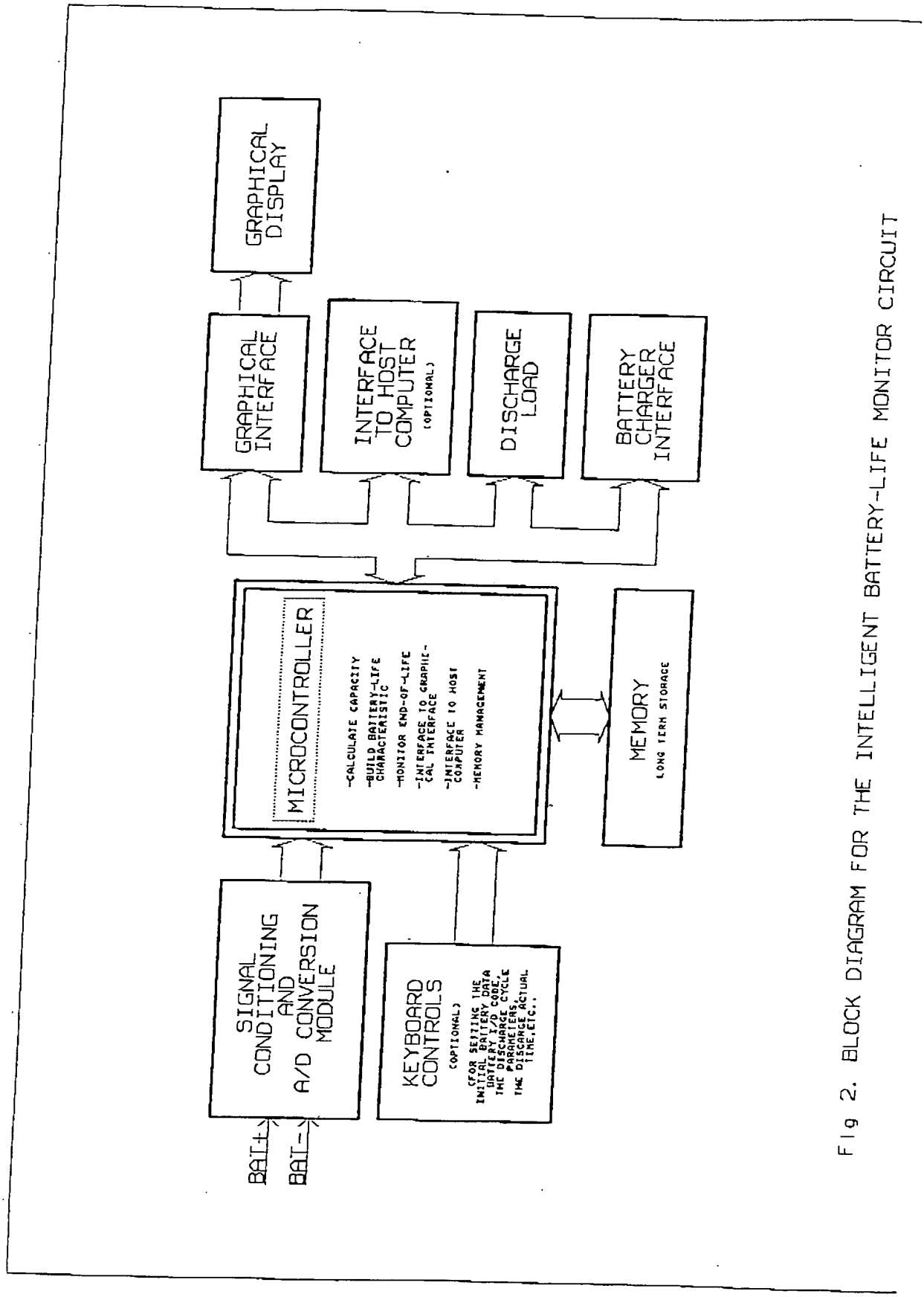

Fig 2. BLOCK DIAGRAM FOR THE INTELLIGENT BATTERY-LIFE MONITOR CIRCUIT

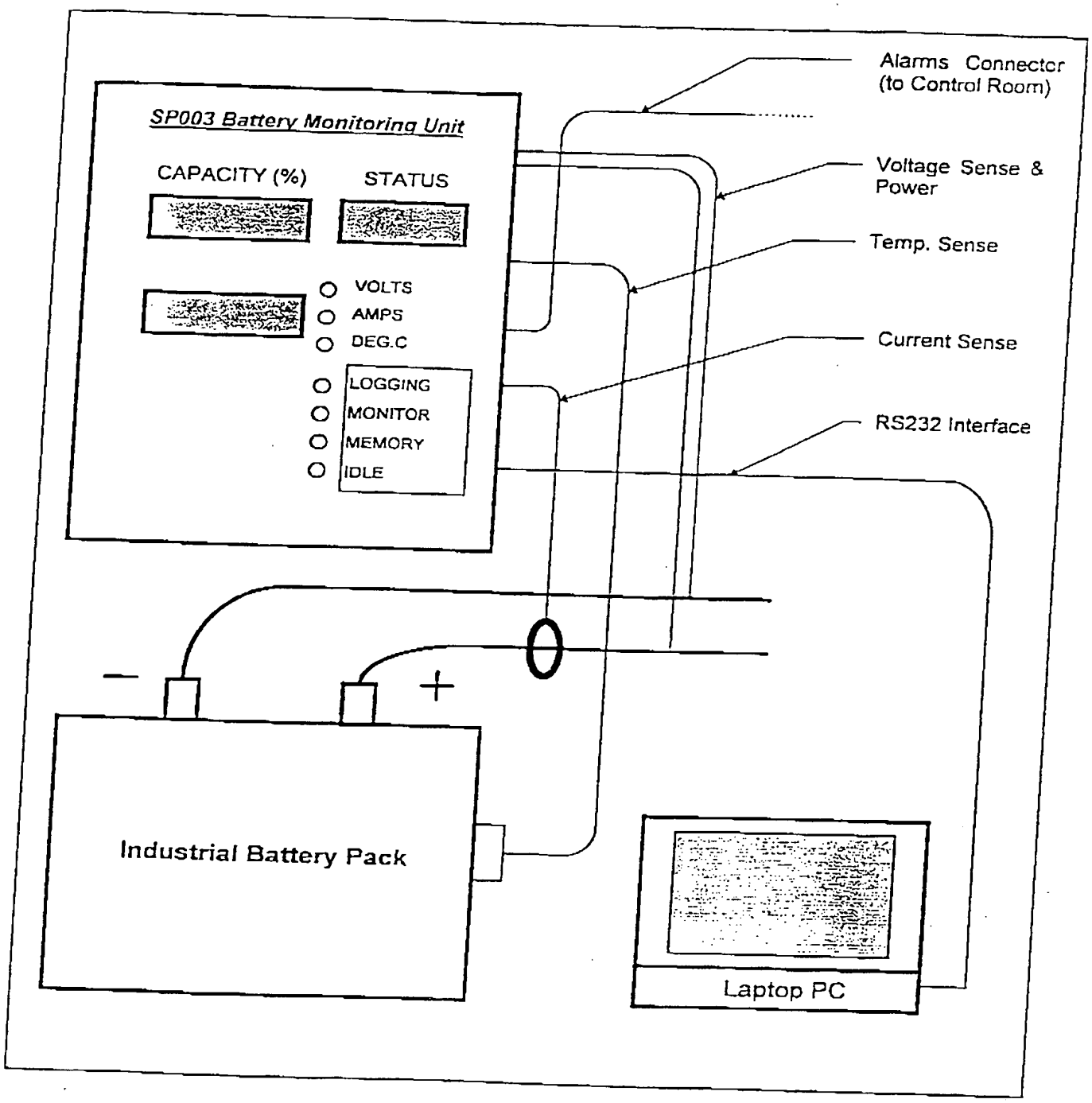

Fig.3 SP003 Hardware Unit